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Digitization of the historical Herbarium of Giovanni Giannini at Pisa (PI-GIANN)

Francesco Roma-Marzio[1], Gabriele Gallerini[2], Lorenzo Peruzzi[1,2]

1 *Botanic Garden and Museum, University Museum System, University of Pisa, Via Luca Ghini 13, 56126 Pisa, Italy* **2** *PLANTSEED Lab, Department of Biology, University of Pisa, Via Derna 1, 56126 Pisa, Italy*

Corresponding author: Francesco Roma-Marzio (francesco.romamarzio@unipi.it)

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Abstract

The herbarium digitization aligns with global efforts to modernise natural collection data and facilitate broad reuse. In this framework, the Herbarium of Giovanni Giannini (1793–1871) conserved in the Herbarium of the University of Pisa (international code PI) was digitized. The Herbarium is composed by 25 packages of plants, algae, fungi, and lichens. Metadata were entered into the online database Virtual Herbaria JACQ and mirrored into a personalized virtual Herbarium of the Botanic Museum. After the completion of the digitization process, the number of specimens preserved in the Herbarium amounts to 1,314. Besides Giannini, who collected 98.5% of the specimens, four other collectors are represented: Benedetto Puccinelli, Lorenzo Chiostri, Pietro Savi, and Attilio Tassi. Most specimens were collected in Tuscany in the province of Lucca (72%). Based on specimens conserved in PI-GIANN, *Centaurea phrygia* subsp. *pseudophrygia* should be considered as at least historically occurring in Tuscany, while *Euphrasia officinalis* subsp. *kerneri* is newly recorded as historically occurring in the province of Lucca. The digitization and revision of PI-GIANN herbarium provide a re-evaluation of a historically important collection, preserving valuable historical occurrences, including several Italian endemic, alien, threatened, or locally extinct species.

Keywords

Herbaria, historical botanical collection, history of botany, museology, specimen metadata, taxonomy

Introduction

Herbarium digitisation – i.e. the capture of images and metadata from specimen labels – and publishing in open access are crucial modern tasks providing numerous benefits of remote access to collections (Davis 2023), being the essential first step in

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transforming the vast amount of data associated with a physical specimen into flexible digital data formats that are accessible, usable, and useful (Hedrick et al. 2020). In this way, all the information hidden in an overwhelming pile of specimens can be summarised, categorised and manipulated, in order to retrieve specific information (Roma-Marzio et al. 2023). Particularly, historical specimens are often accompanied by fragmentary label information, so that providing a link to correct metadata is crucial to make them accessible for researchers worldwide (Reiner-Drehwald et al. 2022).

Also in the Italian context, recent studies have demonstrated that even small and poorly known historical herbaria can represent key sources of information for reconstructing past floristic patterns, documenting species no longer recorded in a given area, and supporting long-term biodiversity and conservation research (e.g., Tomei 2015; Gargano et al. 2018; Fascetti et al. 2020; Brancaleoni et al. 2021; Marconi 2021; Tomei and Trimarchi 2022; Fiaschi et al. 2025).

In this framework, the Herbarium of the University of Pisa (PI is the international code according to Thiers 2020 onwards), started a process of digitization in November 2017. According with the Herbarium's policy, digitization efforts focus on four main directions (Roma-Marzio et al. 2020): 1) digitization of all type specimens and original material (e.g., Roma-Marzio et al. 2018), 2) digitization of all newly acquired specimens and those revised by specialists, 3) digitization of specimens linked to the activity of Gaetano Savi (1769–1844) (Astuti et al. 2019), and 4) digitization of specific separate collections.

As of January 2026, 65,000 specimens have been digitized and made freely accessible, including 524 type specimens. Among the fully digitized separate collections are the herbarium of Michele Guadagno (1878–1930) (Roma-Marzio et al. 2023), the collection of pteridophytes gathered by Giuseppe Raddi (1770–1829) during his expedition to Brazil (1817–1818) (Cecchi et al. 2018), and two small bound herbaria attributed to Antonio Bottini (1859–1931) (Maccioni et al. 2024).

One of the separate collections preserved at the Herbarium of Pisa is the herbarium of Giovanni Giannini (1793–1871) (PI-GIANN hereafter), that holds historical and scientific significance. Giovanni Giannini was born the 1st of December 1793 in Tereglio, a locality in the province of Lucca (Tuscany). He graduated in Medicine from the University of Bologna and, in 1822, spent about a year in Goletta (Tunisia) working as a public health physician (Peruzzi 2023). Giannini focused particularly on the collection of spontaneous plants of the northern Apennine and Apuan Alps as also highlighted by Ferretti et al. (2023), who studied a manuscript by Giannini preserved at the Science Library of the University of Florence, containing a list of 399 species with their collection localities. Over the course of his life, Giannini assembled the specimens gathered through his research into two herbaria (Caruel 1872; Peruzzi 2023). The first, comprising approximately 5,200 specimens, is now preserved at the Liceo Classico "Silvio Pellico" in Cuneo (Ferretti et al. 2023). The second, consisting of 25 small packets, is held at the Herbarium of Pisa and was the subject of a study by Tomei and Riva (1998). The herbarium was donated to the Botanical Garden and Museum of Pisa after the death of Giovanni Giannini by his brother Adriano, under the directorship of Théodore Caruel (Tomei and Riva 1998), although only in 1930 Ugolino

Martelli (1860–1934), during his brief period as director of the Botanic Garden of Pisa, discovered this collection, together with others of notable historical interest, in the storerooms of the Botanical Garden and Museum of Pisa (Martelli 1931).

The passion and dedication to botany of Giovanni Giannini led him to become a prominent figure in the context of Tuscan and Italian floristic studies during the first half of the 19th century, establishing himself as a respected botanist among scholars of the period, such as Antonio Bertoloni (1775–1869), Filippo Parlatore (1816–1877), Théodore Caruel (1830–1898), Cesare Bicchi (1818–1906), and Benedetto Puccinelli (1808–1850). His herbarium specimens and observations contributed to the compilation of the main floras of the time, in which Giannini is repeatedly mentioned and acknowledged, see e.g., Flora Italica (Bertoloni 1833–1854), Synopsis plantarum in agro lucensi sponte nascentium (Puccinelli 1841), Flora Italiana (Parlatore 1848–1875; Caruel 1884–1894), or Prodromo della Flora Toscana (Caruel 1860–1864).

The aim of this paper is to illustrate the digitization process of the Herbarium Giannini, which made the collection freely accessible to all scholars. The digitization of the specimens allowed the extraction and synthesis of all information recorded on the labels concerning collectors, localities, collection periods, and taxonomic data associated with the specimens. In addition, to identify potential floristic novelties, a comparison with the regional and local floras (Peruzzi et al. 2019 onwards) was carried out.

Materials and methods

PI-GIANN, currently stored inside one cabinet of 100 × 73 × 51 cm, is composed by 25 packages of plants, algae, fungi, and lichens. Each package consists of two paperboards covered with marbled paperboard, inside which the specimens are arranged within folded sheets of watermarked cotton paper (Fig. 1). On the top of the paperboards there is a label reporting the number of the package and a Linnaean circumscription, mainly based on the number of stamens. In most cases the specimens are not mounted, and only rarely they are fixed to the sheet with small strips of gummed paper. The specimens are accompanied by a label, either loose or, in some cases, pasted in the lower right corner of the sheet, and they usually measure approximately 7 × 4 cm.

The herbarium is accompanied by a catalogue handwritten by Giannini himself. However, according to Tomei and Riva (1998), the catalogue most likely refers to the part of Giannini herbarium that is preserved in Cuneo, since the species listed in the catalogue often differ from those found in the herbarium held in Pisa.

The digitization process followed the same workflow implemented during the digitization of other collections at Pisa (Roma-Marzio et al. 2023). Prior to the acquisition of the images, a unique identification number (ID hereafter) was stamped on each specimen, then, the digitization procedure followed two distinct steps: 1) acquisition of high-resolution digital images and 2) label data (metadata) acquisition. Concerning the image acquisition, each specimen was scanned using a Bookeye 4 Professional planetary scanner producing a 600 dpi and 24-bit colour depth image

Figure 1. Cabinet where the Herbarium of Giovanni Giannini at the Botanic Museum of the University of Pisa is preserved (top left); one of the 25 packages (top right), and an example of a specimen (bottom).

in .tiff format. Each scan was accompanied by a metric and colorimetric reference. After the acquisition, each image was renamed using the ID assigned to the specimen and uploaded on a web server of the University of Pisa. Metadata were entered into the online database Virtual Herbaria JACQ (http://www.jacq.org/), a continu-

ously developing consortium of virtual herbaria located in Vienna (Bräuchler et al. 2021). By means of the .csv file produced by JACQ, we also set up a personalized Virtual Herbarium of the Botanic Museum (https://erbario.unipi.it), that mirrors the data inserted into JACQ. At the end of the digitization process, each package was marked with a stamp ("D") to indicate that the digitization process was completed. Concerning the georeferentiation, coordinates were inferred from the geographical information reported on the label, which range from very precise indications of the locality to very generic indications of a wide geographical area. Furthermore, to decipher localities on the handwritten labels and/or to identify the coordinates of difficult-to-locate sites, we referred to Ferretti et al. (2023).

As highlighted by Tomei and Riva (1998), most of the specimens in PI-GI-ANN were collected in the province of Lucca. Accordingly, to detect potential floristic novelties, we carried out a comparison of the specimen records of vascular plants with data reported by Pierini and Peruzzi (2014) and in other recently published local floras (e.g., Arrigoni et al. 2016; Pierini and Peruzzi 2025) as well as records stored in Wikiplantbase #Italia (Peruzzi et al. 2019 onwards). When the scientific name on the label matched the accepted name reported by Pierini and Peruzzi (2014) or was listed among the known synonyms, we opted for a reassignment by default of the name recorded by Giannini. Otherwise, nomenclature was updated primarily according to the Portal to the Flora of Italy (Martellos et al. 2020; v. 2025.1). We referred to Plants of the World Online (POWO 2025) only in those cases where relevant synonyms were not reported in the Portal to the Flora of Italy. Furthermore, if necessary, we carried out a direct check of the identification of the specimens using the identification keys reported by Pignatti et al. (2017a, 2017b, 2018, 2019). For fungi, bryophytes, liverworts and lichens, no nomenclatural update was performed, and the names were retained as originally reported by Giannini on the specimen labels.

For the analysis of the plant families, we updated the default taxonomic circumscription used by JACQ according to PPG I (2016) for ferns and fern allies, to Christenhusz et al. (2011) for gymnosperms, and to APG IV (2016) for angiosperms. QGIS 3.10 software was used to draw the map.

Results

The number of specimens preserved in PI-GIANN amounts to 1,314. Among the digitized specimens, there is one sheet bearing only plants without label and 52 sheets bearing only labels with plants absent or almost destroyed/reduced to small fragments. The content of the parcels range from a minimum of two specimens (package nr. 9) to a maximum of 126 (package nr. 5), except for package nr. 7, which is empty.

From a taxonomic point of view, the Herbarium includes fungi (11 specimens corresponding to 0.8% of the collection), bryophytes (42; 3%), liverworts (8; 0.6%), lichens (26; 2%), pteridophytes (31; 2.5%), gymnosperms (5; 0.4%), non-eudicot dicots (4; 0.3%), monocots (220; 16.8%), and eudicots (966; 73.6%). As concerns the vascu-

lar plants, after the nomenclatural updates, 115 families, 568 genera and a total of 1.115 specific and subspecific taxa can be found in PI-GIANN. The most represented families are Asteraceae (142; 10.8%), Fabaceae (85; 6.5%), Poaceae (76; 5.8%), Apiaceae (63; 4.8%), Brassicaceae (58; 4.4%), and Rosaceae (54; 4.1%). The most represented genera are *Trifolium* (24; 2%), *Ranunculus* (20; 1.6%), *Carex* (17; 1.4%), *Euphorbia* and *Veronica* (16; 1.3%). For 154 specimens the nomenclatural update was not sufficient, and a check of the identification was required. A complete list of all species with original nomenclature and updates is available in the Suppl. material 1.

From a geographical perspective, excluding 352 specimens lacking any geographical indication, all other specimens were collected in Italy. Among them, only 7 come from Lake Baccio in Emilia-Romagna, while the remaining 955 were all collected in Tuscany. Of the Tuscan specimens, only three were collected in the province of Pistoia (Lago Nero), one in the Botanic Garden of Pisa, while the remaining 951 were all collected in the province of Lucca (Fig. 2). The most represented localities are Tereglio (155 specimens), Mt. Rondinaio (66), Musceta (48), Valdottavo (47), Mt. Prato Fiorito (46), and Pozzuolo (37).

Flowering and/or fruiting months are often indicated, whereas the collection date is reported for only 63 specimens (fewer than 5%). From the analysis of this small portion of specimens for which a collection date is provided, the time span covered ranges from 1836 to 1868. Besides Giannini, who collected 98.5% of the specimens, four other collectors are represented: Benedetto Puccinelli (16 specimens), Lorenzo Chiostri (2), Pietro Savi (1), and Attilio Tassi (1). Finally, in 440 labels (33.5%), references are provided regarding the following floras and iconographic works: Flora Danica by Georg Christian Oeder (1728–1791; 262 specimens), Flora Londinensis by William Curtis (1746–1799; 164 specimens), Flora Lucchese by Benedetto Puccinelli (6), Flora Pedemontana by Carlo Allioni (1728–1804; 3), Flora Bocconea by Paolo Boccone (1633–1704; 2), Flora Napolitana by Michele Tenore (1780–1861; 1), Materia Medica Vegetabile Toscana (1), and Flora Pisana by Gaetano Savi (1769–1844; 1).

Discussion

The integration of images and metadata into open-access digital platforms such as JACQ and the Virtual Herbarium of Pisa significantly enhances the interoperability of collections, aligning with global efforts to modernise collection data and facilitate broad reuse (Sweeney et al. 2018; Thiers 2024). Accordingly, PI-GIANN is now placed within the broader digitization movement, that has revolutionized the accessibility of natural history collections in recent years (James et al. 2018; Davis 2023; Roma-Marzio et al. 2023).

We surveyed 1,314 herbarium specimens, the same number reported previously by Tomei and Riva (1998). However, these authors reported 51, and not 52, specimens bearing only labels, with the plants absent or almost completely destroyed. About the collectors, we traced 18 specimens not collected by Giannini, five more than those reported by Tomei and Riva (1998). In addition to Benedetto Puccinelli and Lorenzo

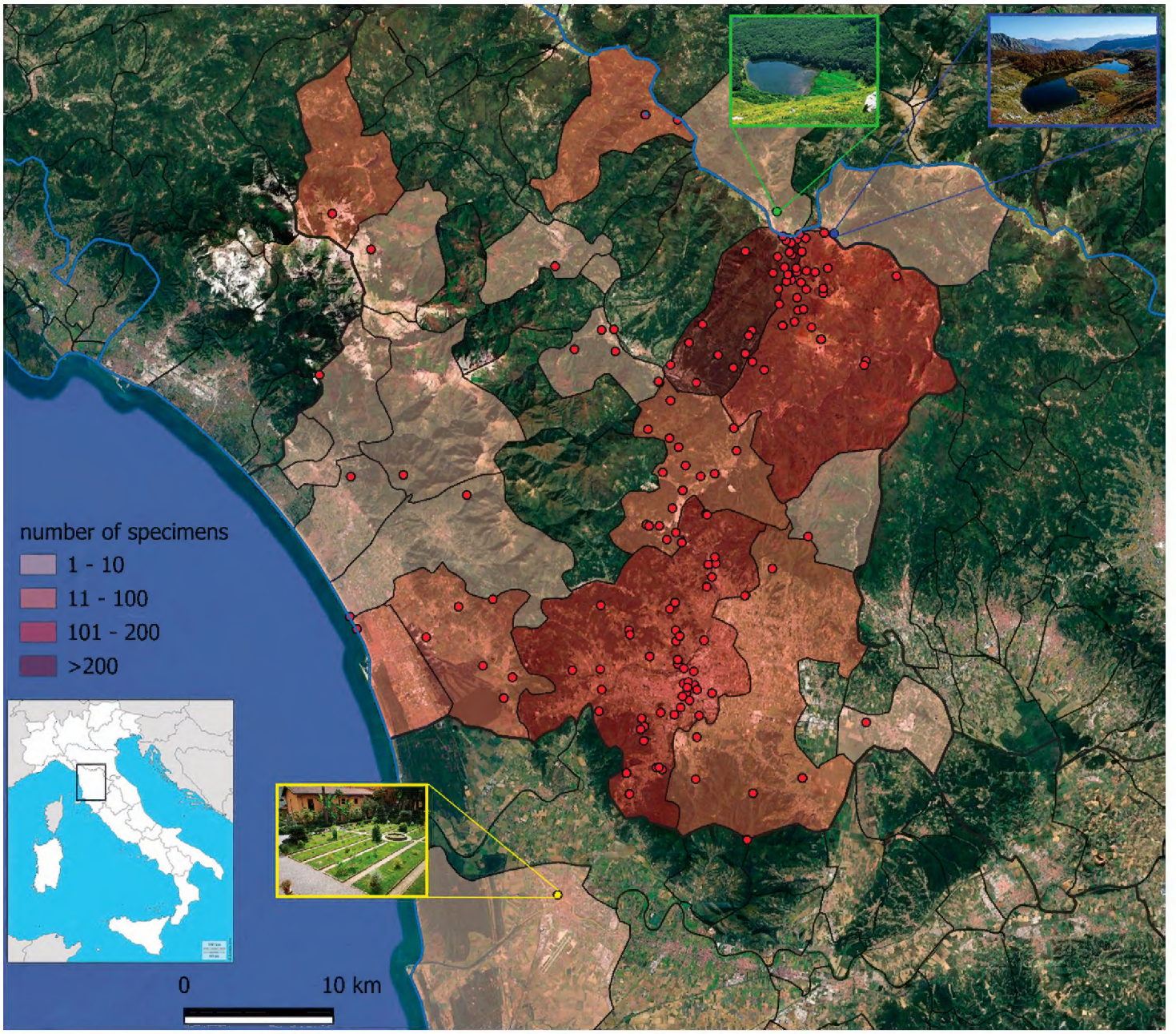

Figure 2. Distribution of the collection localities of the specimens preserved in PI-GIANN and their density by municipality. The three localities outside the province of Lucca are highlighted: Orto Botanico di Pisa (yellow dot), Lago Baccio (green dot), and Lago Nero (blue dot).

Chiostri, already mentioned by these authors, we found specimens collected by Attilio Tassi (*Carlina lanata* L., PI nr. 067282) and Pietro Savi (*Trifolium strictum* L., PI nr. 067911), both lacking collection date and locality. Although different collectors are only marginally represented in PI-GIANN, their presence nonetheless confirms the professional relationships that Giannini maintained with several Tuscan botanists of his time (Giannessi and Olivero 2019; Ferretti et al. 2023). Also, the presence of specimens collected by Giannini in other collections, either in the Pisa Herbarium (Vangelisti et al. 2025) or in other Herbaria (Ferretti et al. 2023), further supports the idea of an active and extensive network of specimen exchanges in which Giannini played a significant role. Even though dated specimens represent less than 5% of the collection, they nonetheless show that Giannini was actively collecting between the ages of 43 and 75. This confirms his activity until the final years of his life, as illustrated by the specimens of *Rubus caesius* L. (PI nr. 068350) collected in Valdottavo three years before his death.

Tomei and Riva (1998) indicated that the collection was entirely composed of material collected within the province of Lucca in Tuscany. On the contrary, the digitisation process revealed the presence of seven specimens collected from Lago Baccio in Emilia-Romagna (province of Modena), three specimens collected at Lago Nero (province of Pistoia) and a specimen collected at the Botanic Garden of Pisa. Among the specimens collected at Lago Baccio, *Cardamine amara* L. subsp. *amara* (PI nr. 068219), *Carex canescens* L. (under the name *C. curta* Gooden.; PI nr. 068563), *Eriophorum scheuchzeri* Hoppe (under the name *Eriophorum capitatum* Host; PI nr. 068385), and *Menyanthes trifoliata* L. (PI nr. 067483) are listed among the species occurring in a limited number of sites and showing populations with few individuals in the province of Modena (Alessandrini et al. 2010). According to the same authors, *Callitriche palustris* L. (under the name *C. verna* L.; PI nr. 068714) is listed among declining species in the province. Among the specimens collected at Lago Nero, *Rorippa amphibia* (L.) Besser (under the name *Sisymbrium terrestre* Savi; PI nr. 068223) is not reported for the area by Romagnoli and Foggi (2005), while *Micranthes engleri* (Dalla Torre) Galasso, Banfi & Soldano (under the name *Saxifraga stellaris* L.; PI nr. 068075) is listed as a species protected in Tuscany according to the Regional Law 56/2000, Annex C. The specimen of *Hippuris vulgaris* L. in PI-GIANN (PI nr. 068711) is the only one collected in the Botanic Garden of Pisa, and it bears no date. As noted by Giannini on the label, he never encountered this species in the wild: "*Questa pianta la presi nell'Orto Pisano ove era coltivata in un laghetto. La posi qui credendo di trovarla nel lucchese ma non fu vero*" [I collected this plant in the Botanic Garden of Pisa, where it was cultivated in a small pond. I placed it here believing I would find it in the Lucchese area, but this proved not to be the case]. The presence of this species cultivated in the Botanic Garden of Pisa is also confirmed by another specimen preserved in the Herbarium of Giovanni Arcangeli (PI nr. 069938) and collected in 1865. The collection date referred to cultivated plants confirms what stated by Pierini and Peruzzi (2014) who report that the only known locality for *Hippuris vulgaris* (classified as Endangered in Italy according to the IUCN protocol; Orsenigo et al. 2020) in the province of Lucca dates to 1937, more than sixty years after Giannini's death, from a record near Viareggio (Vannini 1937).

The families represented in PI-GIANN account for 72% of the 159 vascular plant families recorded for the province of Lucca by Pierini and Peruzzi (2014). Besides Asteraceae – the most species-rich family in both datasets – the relative abundance of the other major families differs: in PI-GIANN they are, in decreasing order, Fabaceae, Poaceae, Apiaceae, and Brassicaceae, whereas in the provincial flora the order shifts to Poaceae, Fabaceae, Brassicaceae, and Caryophyllaceae (Pierini and Peruzzi 2014). At the genus level, PI-GIANN includes 568 genera, representing 55% of those reported for the province of Lucca (Pierini and Peruzzi 2014). Also the relative abundances of genera show slight differences between the two datasets, since the three genera most represented in PI-GIANN are *Trifolium*, *Ranunculus*, and *Carex*, whereas Pierini and Peruzzi (2014) list *Carex*, *Trifolium*, and *Centaurea*. These patterns likely reflect

a collecting bias, associated with the personal preferences of the main collector, as already highlighted for other herbarium collections in large-scale digitization projects (Daru et al. 2017).

The comparison between the scientific names reported on the specimen labels and those already known for the province of Lucca (Pierini and Peruzzi 2014) showed that 1,085 taxa have been already recorded (700 using the same name reported by Giannini, 385 as synonyms of currently accepted taxa), whereas 142 are not mentioned. After the nomenclatural and identification checking, it was possible to highlight that the specimen reported by Giannini as *Centaurea austriaca* Willd. (PI nr. 067349) is referred to *Centaurea phrygia* L. subsp. *pseudophrygia* (C.A.Mey.) Gugleras, a subspecies reported as doubtfully occurring in Tuscany (Bartolucci et al. 2024). Based on this specimen, *C. phrygia* subsp. *pseudophrygia* should therefore be regarded as at least historically occurring in Tuscany. Two taxa were not reported so far for the province of Lucca (Pierini and Peruzzi 2014; Peruzzi and Bedini 2015 onwards): *Euphrasia officinalis* L. subsp. *kerneri* (Wettst.) Eb.Fisch. (PI nr. and 068168, 068169, 068170) and *Avena sativa* L. subsp. *praegravis* (Malzev) Mordv. (PI nr. 068430). This latter subspecies, however, is a cultivated variety lacking taxonomic value, and should therefore be regarded as a synonym of *Avena sativa* L. (E. Banfi comm. pers.), despite it is currently accepted in the Portal to the Flora of Italy (Martellos et al. 2020; v. 2025.1).

The digitization revealed the presence of 30 specimens belonging to 27 Italian endemic taxa (Peruzzi et al. 2014). Among them *Aquilegia lucensis* E.Nardi (PI nr. 068038), *Carum appuanum* (Viv.) Grande subsp. *appuanum* (PI nr. 068311), *Globularia incanescens* Viv. (PI nr. 068551), *Moltkia suffruticosa* (L.) Brand subsp. *bigazziana* Peruzzi & Soldano (PI nr. 067495), *Pinguicula christinae* Peruzzi & Gestri (PI nr. 068486), *Rhinanthus apuanus* Soldano (PI nr. 068158, 068159), *Siler montanum* Crantz subsp. *apuanum* F.Conti & Bartolucci (PI nr. 068277), *Thliphthisa apuana* (Fiori) P.Caputo & Del Guacchio (PI nr. 068531), and *Viola ferrarinii* Moraldo & Ricceri (PI nr. 067561, 067562) are endemic to Apuan Alps and/or Northern Apennine (Baldini et al. 2010; Moraldo et al. 2011; Peruzzi and Gestri 2013; Nardi 2016; Conti et al. 2021; Pierini and Peruzzi 2025), whereas *Astrantia pauciflora* Bertol. subsp. *pauciflora* (PI nr. 068275), *Salix crataegifolia* Bertol. (PI nr. 068623), and *Silene lanuginosa* Bertol. (PI nr. 068098) are narrow endemic to Apuan Alps (Pierini and Peruzzi 2025).

The specimen of *Taraxacum pauckertianum* Hudziok (PI nr. 060687, Fig. 3) is the only documented record in Italy of this species, to be considered extinct at national level (Domina et al. 2025). Also, the specimens of *Utricularia minor* L. (PI nr. 068484) collected at "*Pollini del D. Tabarracci*" in Monte Pisano, and of *Vaccinium oxycoccos* L. (PI nr. 068125) collected "*in palude Bientina*", belong to other two species that are regionally extinct in Tuscany (Bartolucci et al. 2018; Domina et al. 2025) providing historical evidence of their occurrence at the recorded localities (Peruzzi and Bedini 2015 onwards; Maccioni et al. 2022). Another important specimen is that of *Santolina etrusca* (Lacaita) Marchi & D'Amato, since it documents the historical occurrence of this central Italian endemic species in northern Tuscany as well, where it became locally extinct during the twentieth century (Angiolini 2001; Peruzzi et al. 2026).

Figure 3. Specimen of *Taraxacum pauckertianum* Hudziok collected by Giannini under the name *Taraxacum palustre* and revised as *T. pauckertianum*.

Remarkably, PI-GIANN preserves 58 taxa included in the Italian Red Lists (Rossi et al. 2013, 2020; Orsenigo et al. 2020), of which six are also considered of high conservation interest according to the recent study by Gennai et al. (2025), focused on Tuscan flora. The occurrence of these species underscores the value of herbarium collections as essential sources of information about plant extinction risk assessments (Nic Lughadha et al. 2019).

The presence of extinct, rare or of high conservation interest species have been reported for other little-known or historical herbarium collections, which have proven crucial in documenting past floristic diversity and in preserving evidence of species that are currently absent or no longer confirmed in specific areas, highlighting the value of historical herbaria for reconstructing former species distributions, assessing local extinctions, and providing long-term baselines for floristic and conservation analyses (Tomei 2015; Gargano et al. 2018; Fascetti et al. 2020; Brancaleoni et al. 2021; Marconi 2021; Fiaschi et al. 2025).

PI-GIANN also preserves 42 specimens of species non-native in Tuscany, including six casual, 24 naturalized, and eight invasive aliens, plus two taxa reported as aliens without a specific status and not confirmed in recent times (Galasso et al. 2024). The presence of these non-native taxa underlines the relevance of historical herbaria for biodiversity monitoring, conservation biology, and invasion ecology (Marín-Rodulfo et al. 2024).

The herbarium PI-GIANN is then a reliable baseline for reconstructing past floristic patterns and evaluating changes in species distributions, a research line recognised as essential in biodiversity studies (Meineke et al. 2018; Heberling et al. 2019).

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Supplementary material 1

Dataset including nomenclatural updates of the specimens and a list of Italian endemics, National IUCN Red List category, and alien status

Authors: Francesco Roma-Marzio, Gabriele Gallerini, Lorenzo Peruzzi

Data type: xlsx

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